



Water cycle extremes in the Mediterranean in a context of climate change

Philippe Drobinski

Institut Pierre Simon Laplace / Laboratoire de Météorologie Dynamique

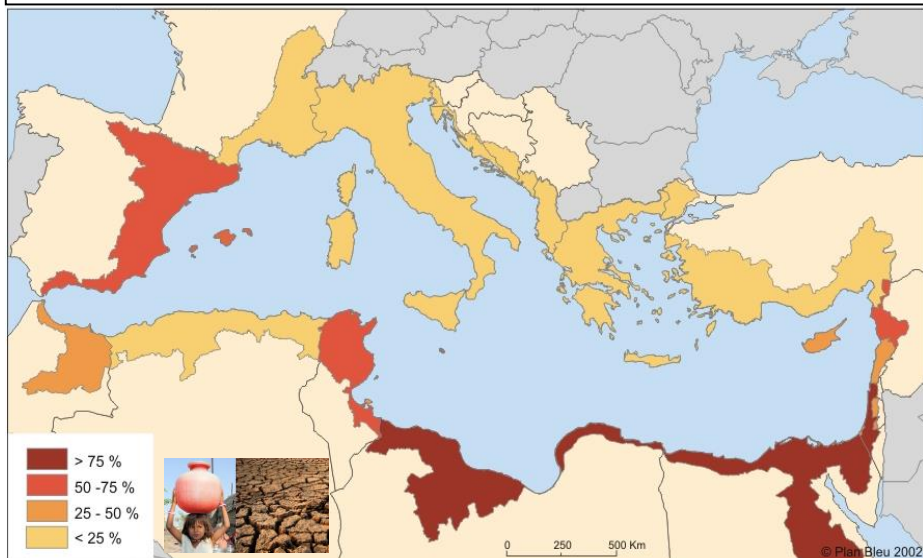
CNRS & Ecole Polytechnique

Palaiseau, France

Two reasons to investigate the Mediterranean water cycle...

Critical water resources and droughts

Water resource exploitation index in 2000



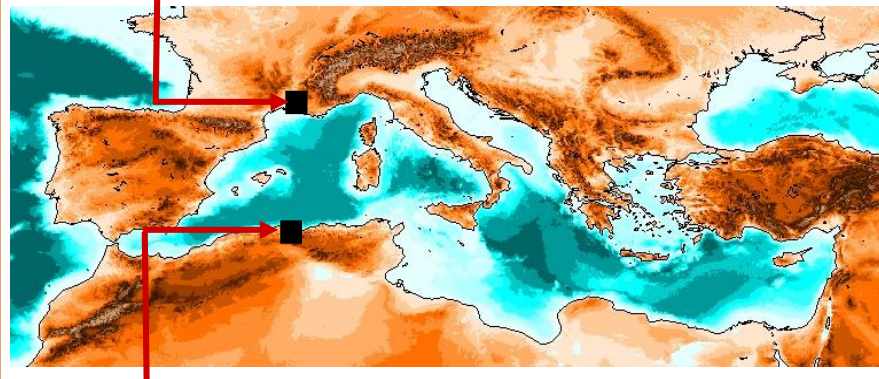
- Demand multiplied by 2 since 1950
- 60 million inhabitants lacking water
- 20 million inhabitants without access to drinkable water

Heavy precipitation and floods

Between 1990 and 2006

- more than 175 flood events
- more than 29 140 M€ damages and 4 500 deaths

- Gard, Sept. 2002: $\sim 700 \text{ l/m}^2$
20 deaths; 1 200 M€ de damages

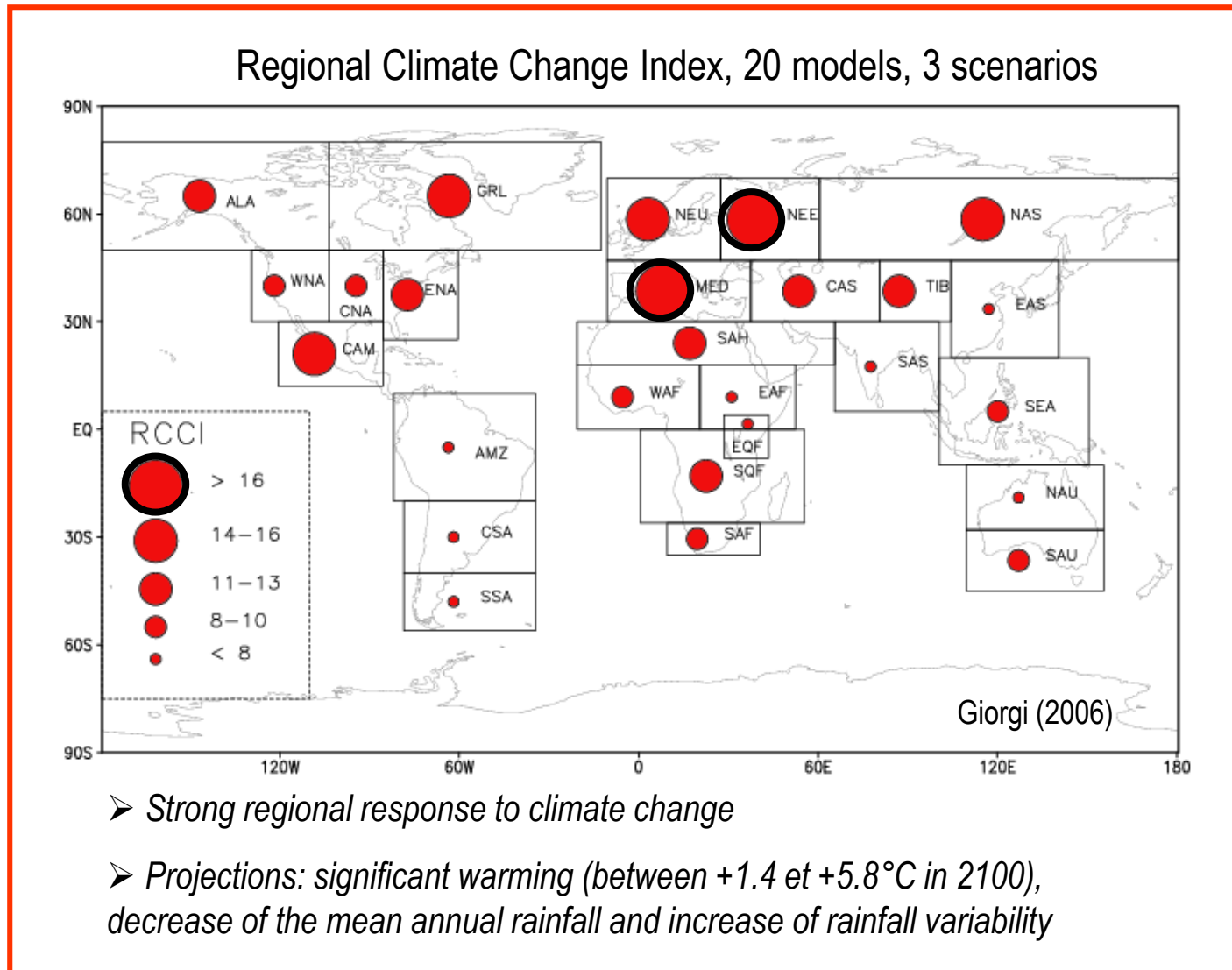


- Alger, nov. 2001: $\sim 260 \text{ l/m}^2$
886 deaths; 4 000 M€ de damages



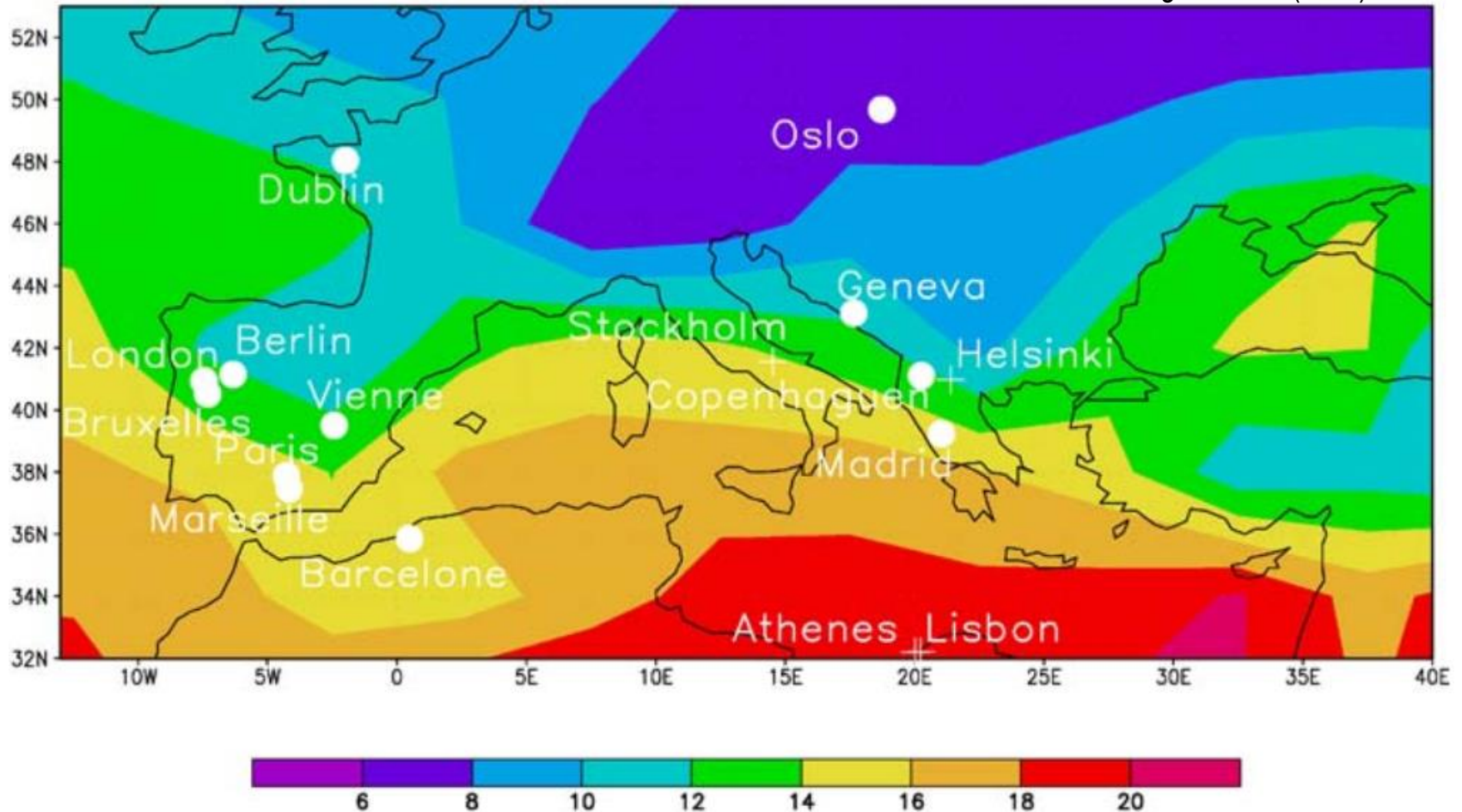
... in a context of climate change

A "hot-spot" of climate change

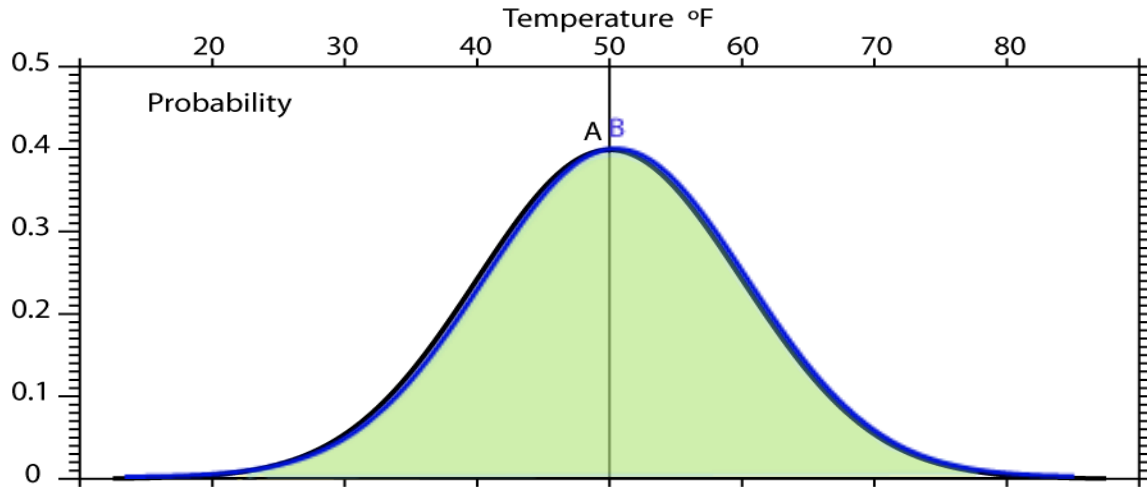


... in a context of climate change

Source: Hallegatte et al. (2007)



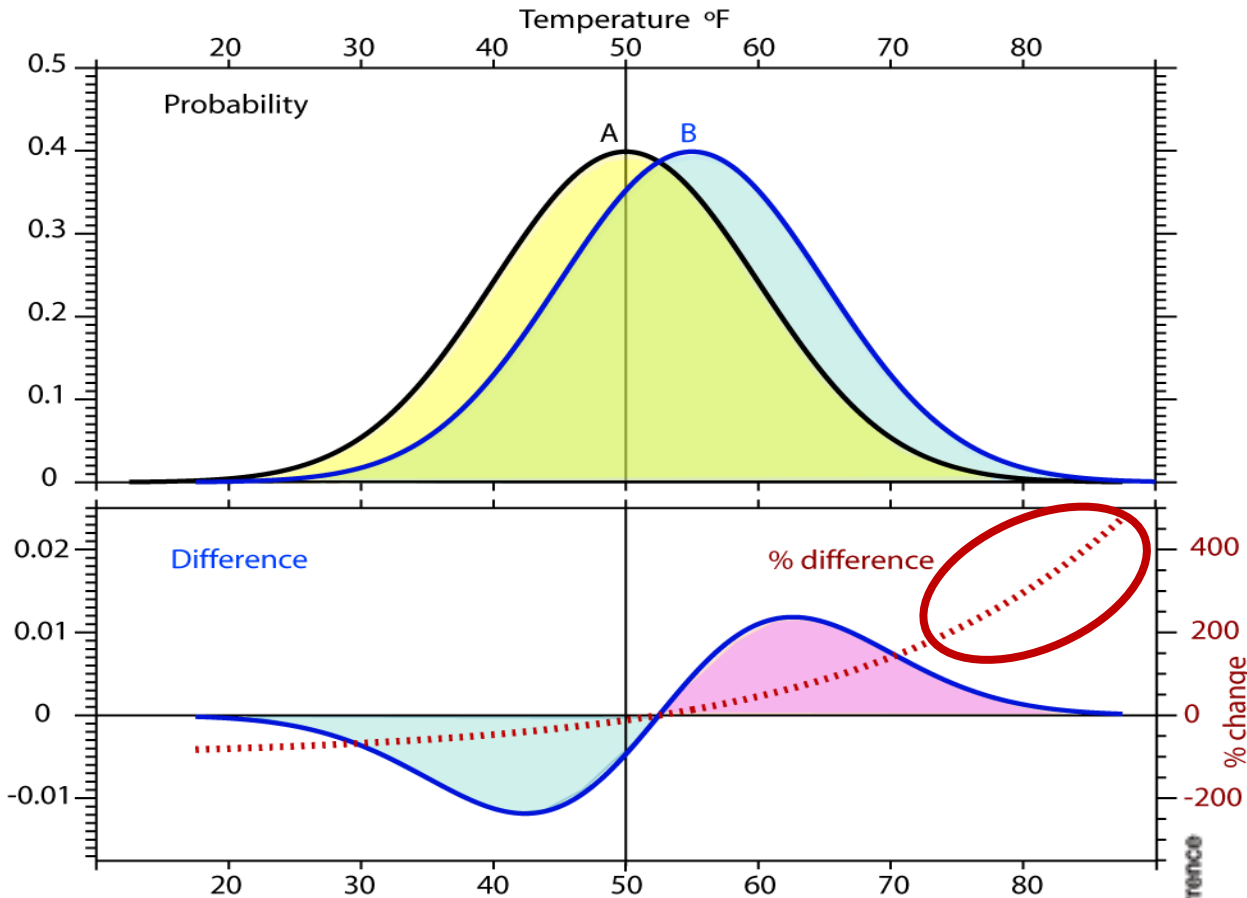
Reason for focus on extremes



Shift in climate: from A to B

Mean A: 50°F, s.d. 10°F

Reason for focus on extremes

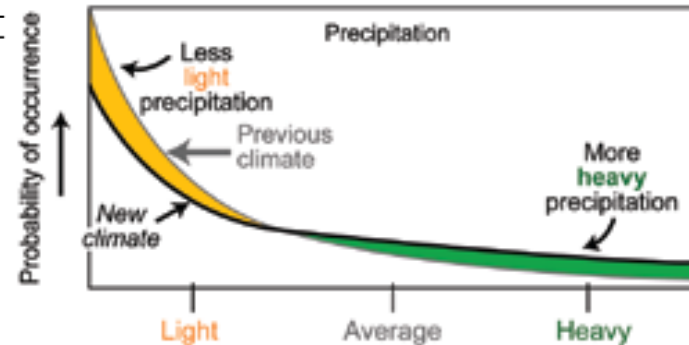


Shift in climate: from A to B

Most of the time the values are the same (green).

Biggest changes in extremes: >200%

Mean A: 50°F, s.d. 10°F
Mean B: 55°F, s.d. 10°F



Reason for focus on extremes

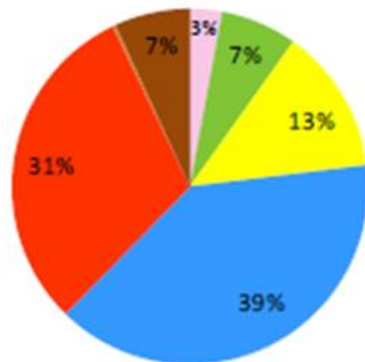
Cost of droughts and heatwaves

- ▶ 2000-2006: 15% of the EU total area and 17% of the EU total population have suffered from the impacts of droughts
- ▶ Most severe event in 2003 with more than 30.000 deaths in Europe (caused by the heatwave)
- ▶ Total cost of drought over the past 30 years: above 100 billion €

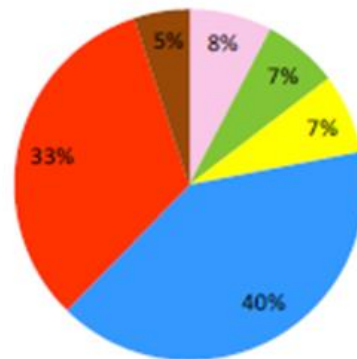
Cost of floods

- ▶ 1998-2002: EU suffered over 100 major damaging floods, including catastrophic floods along the Danube and Elbe rivers in 2002.
- ▶ 1998-2004: floods caused some 700 fatalities, the displacement of about half a million people and at least € 25 billion in insured economic losses

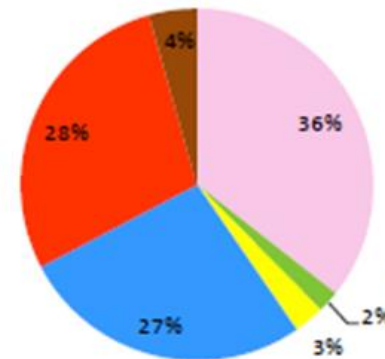
Disaster occurrence



Economic damages



No. affected people



Drought

Extreme temperature

Storm

Wildfire

Earthquake*

Flood**

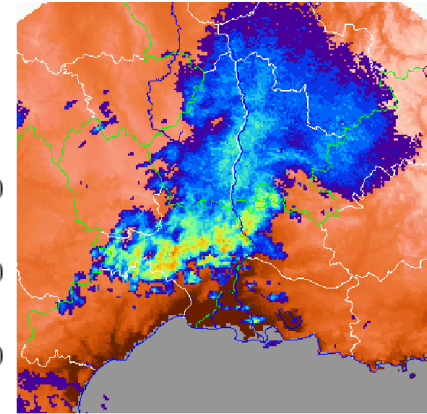
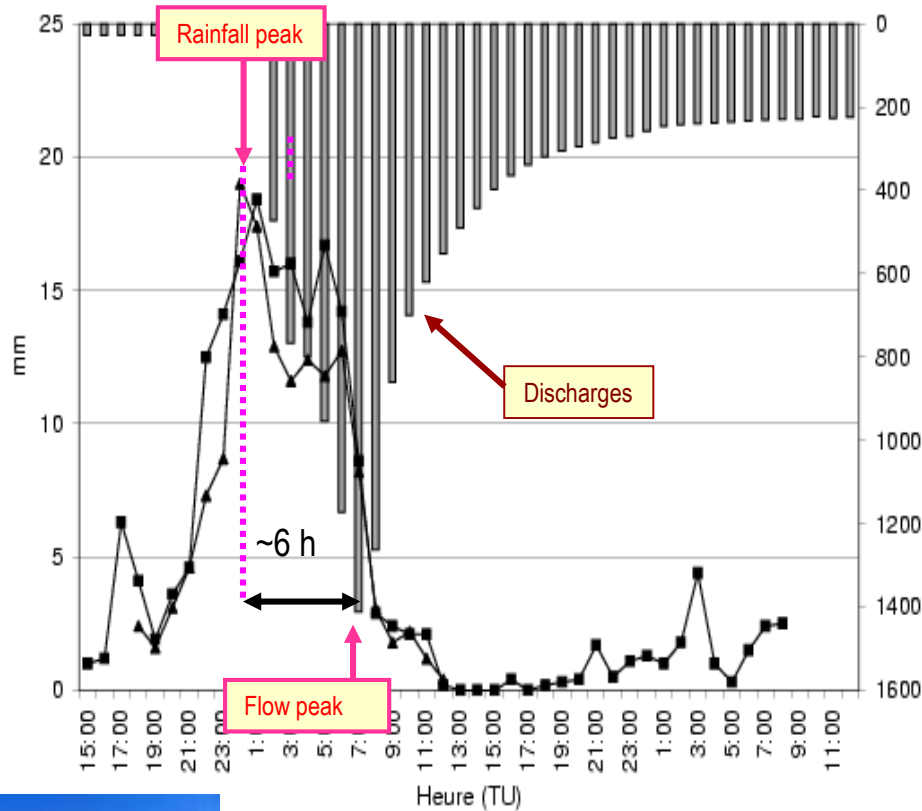
Volcano

* Includes dry mass movements

** Includes wet mass movements

Heavy precipitation and floods

Gardon d'Anduze Watershed (545 km²)



Source: Ducrocq



Gunja - Croatia (May 2014)



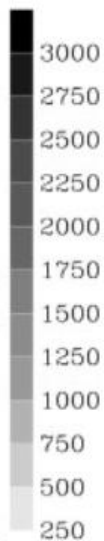
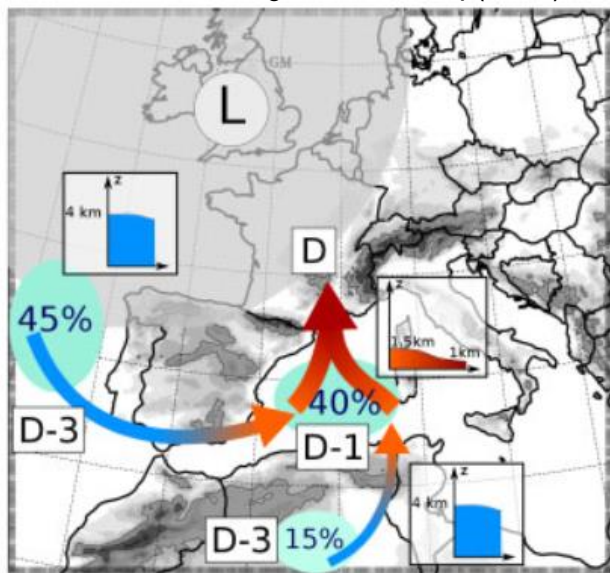
Genoa - Italy (October 2014)



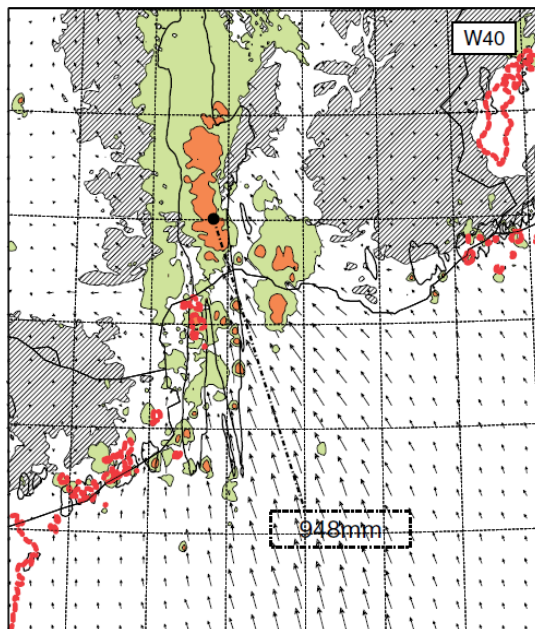
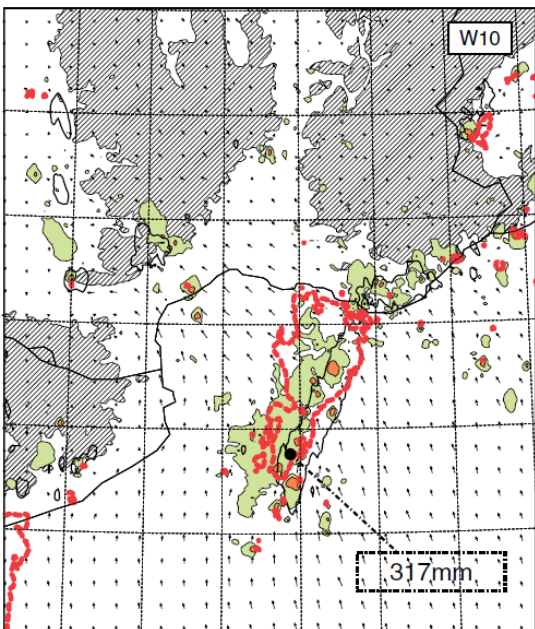
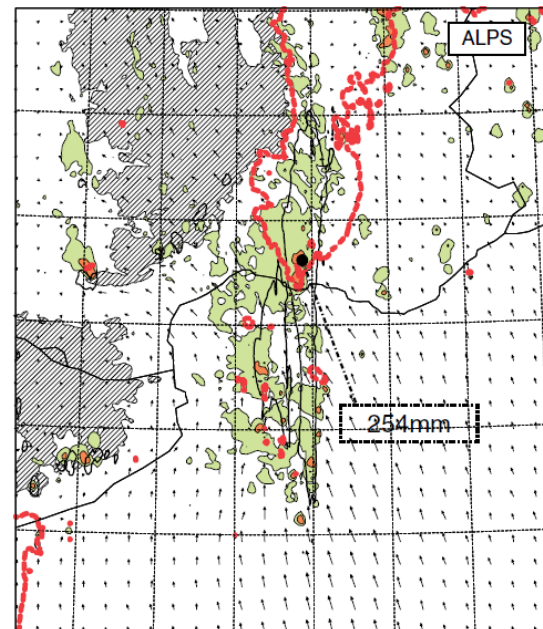
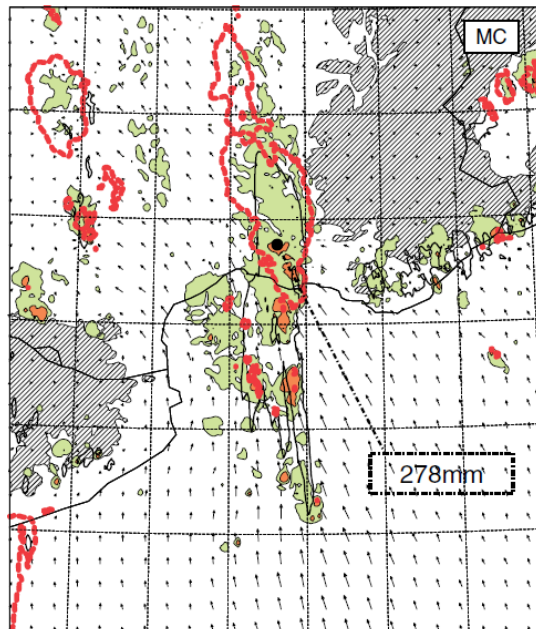
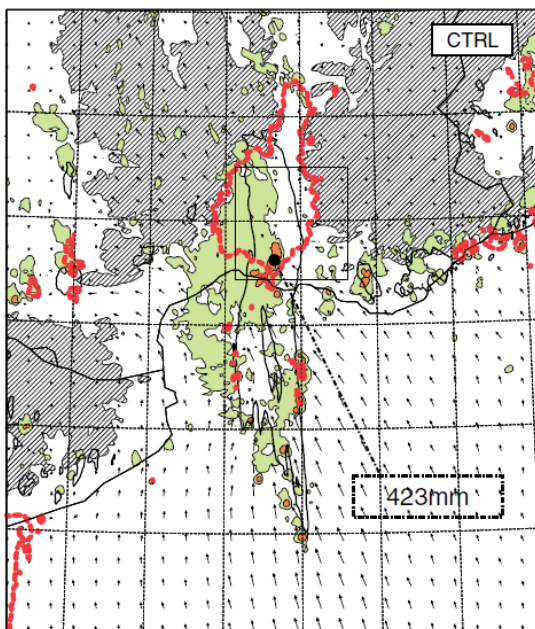
Montpellier - France (September 2014)

Heavy precipitation and floods

Source: Duffourg and Ducrocq (2013)

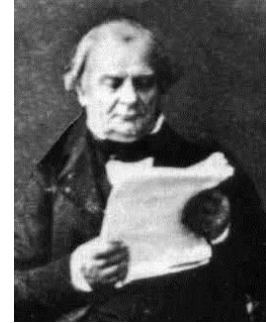


Heavy precipitation and floods



Heavy precipitation and floods

Clausius-Clapeyron (CC) law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature → Air holds more water vapor at higher temperature



$$k = \left(1 - \frac{\delta}{e}\right) \frac{dp}{dt} C.$$

E. Clapeyron (1834)

$$r = C \cdot (s - \sigma) \frac{dp}{dt}.$$

R. Clausius (1850)

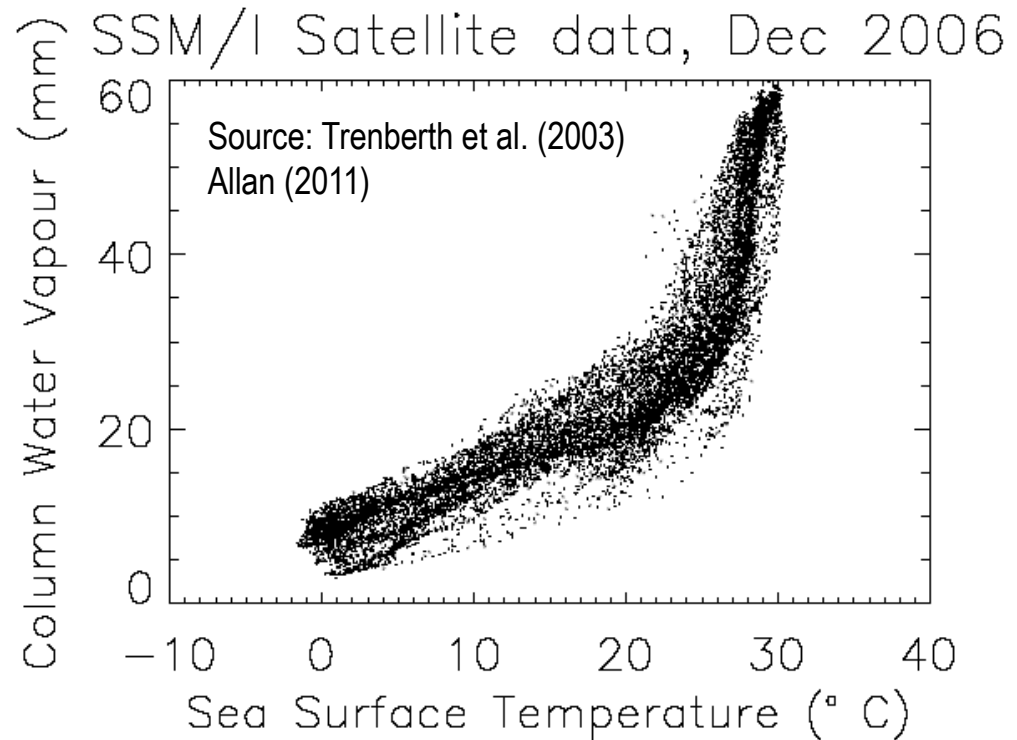


Observations show that this is happening at the surface and in lower atmosphere: 0.55°C since 1970 over global oceans and 4% more water vapor.

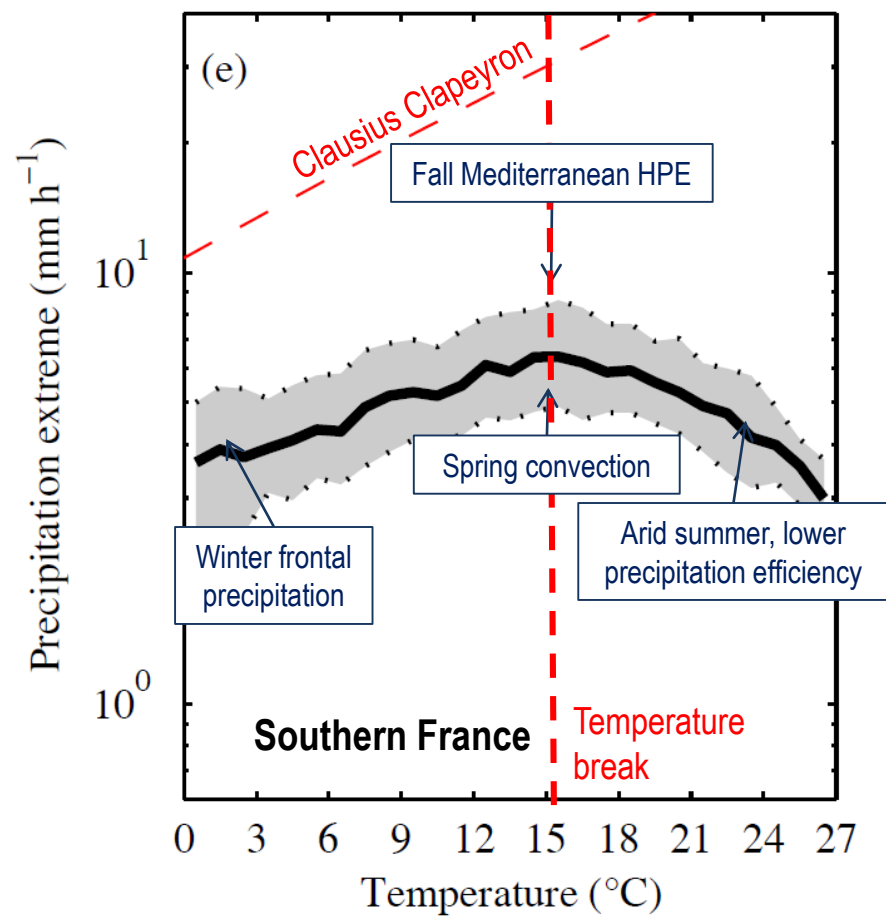
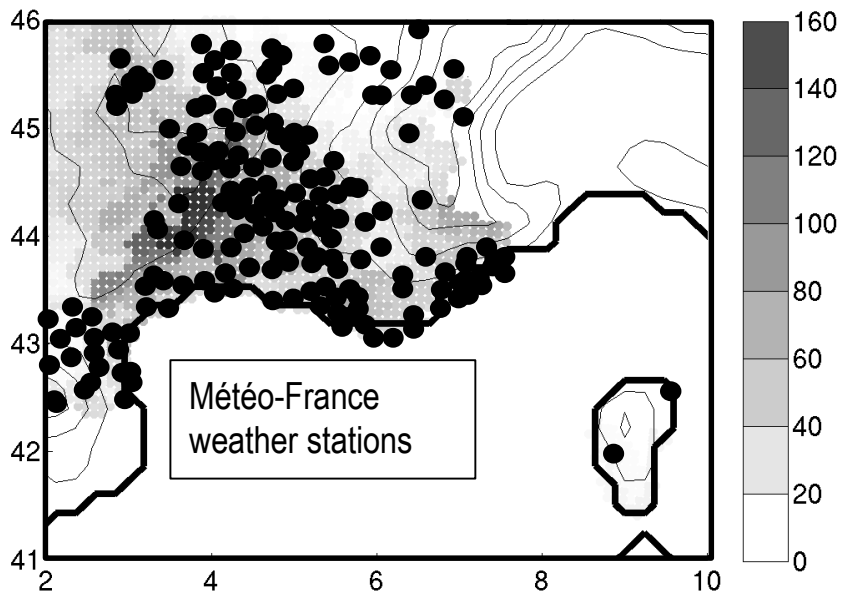
This means more moisture available for storms and an enhanced greenhouse effect



More intense precipitation expected in a warming climate !!!



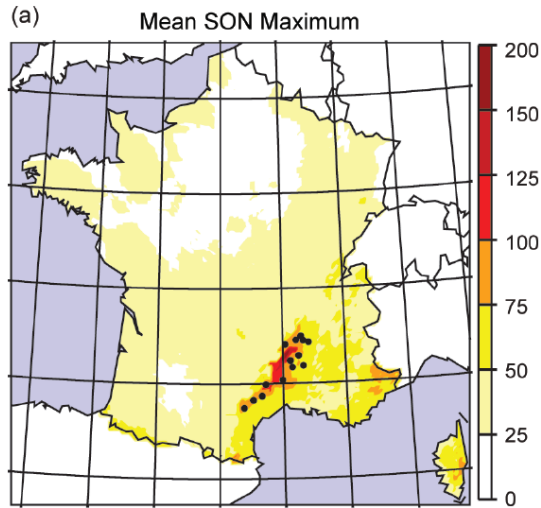
Heavy precipitation and floods



Source: Drobinski et al. (2016)

Heavy precipitation and floods

Vautard et al. (2014)



8 | PLANÈTE

INONDATIONS DANS LE SUD-EST

Intempéries: les raisons d'une désolation

L'arc méditerranéen est pris en tenaille entre le changement climatique et une urbanisation galopante

LES PRÉCÉDENTS DANS LA RÉGION

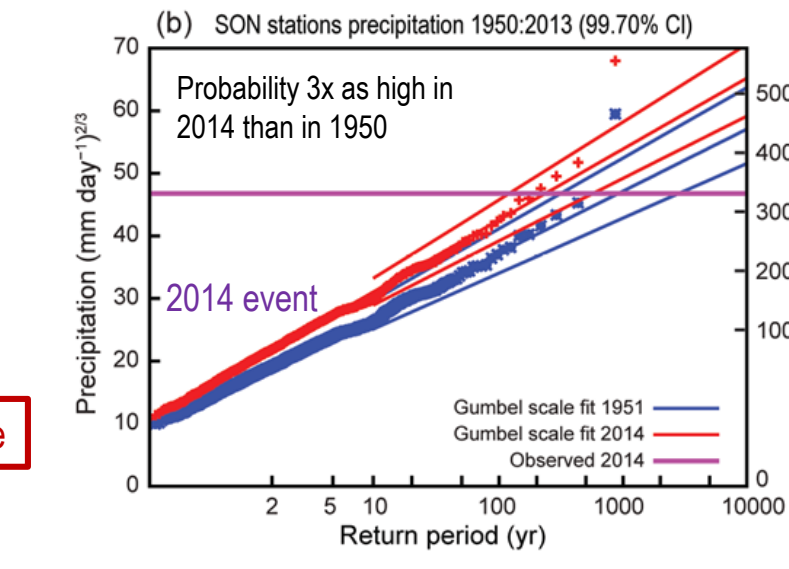
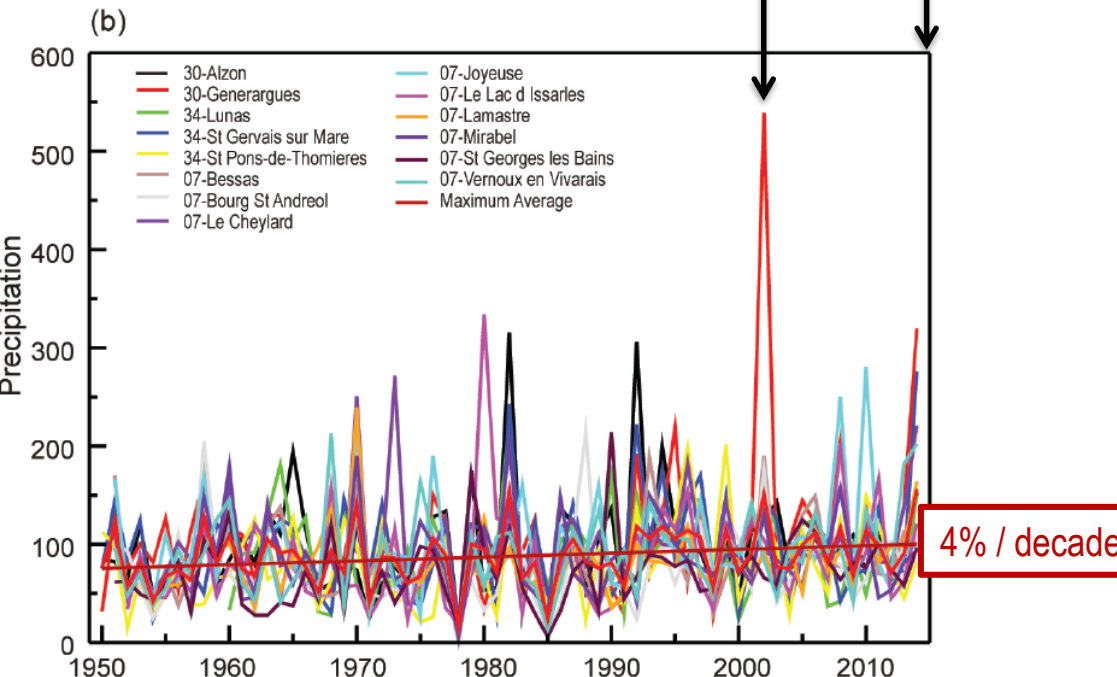
- SEPTEMBRE 1992: 24 morts, dans la Vallée, dont 21 à Nîmes-Bonville.
- NOVEMBRE 1999: 24 morts et 4 disparus dans l'Arc, du Tarn, du Gard, de l'Ardèche, de l'Hérault, de la Lozère, de la Haute-Garonne, de l'Aude et de l'Ariège.
- SEPTEMBRE 2002: 24 morts dans le Gard précipité.
- JUN 2010: 23 morts et 3 disparus dans le Var.
- 2014: 13 morts, entre le 7 septembre et le 23 septembre, dans la Lozère, l'Ardèche, le Gard, le Languedoc, l'Ariège, le Tarn, le Lot, le Lot-et-Garonne, le Gers, le Haut-Rhin, le Jura, le Doubs, le Rhône, le Loiret, le Cher, le Centre, le Maine-et-Loire, le Vendée, le Morbihan, le Finistère, le Bretagne, le Normandie, le Picardie, le Hauts-de-France, le Nord-Pas-de-Calais, le Grand-Est, le Bourgogne-Franche-Comté, le Centre-Val de Loire, le Île-de-France, le Normandie, le Bretagne, le Normandie, le Picardie, le Hauts-de-France, le Nord-Pas-de-Calais, le Grand-Est, le Bourgogne-Franche-Comté, le Centre-Val de Loire, le Île-de-France.

Météo France avait bien annoncé de fortes pluies sur la région. Mais la réalité a été deux fois pire

Il faut réviser ses diques encore une fois, car les pluies sont tombées sur la région, mais pas de la même manière. Les pluies ont été plus fortes, plus longues, plus intenses. Les pluies ont été plus fortes, plus longues, plus intenses. Les pluies ont été plus fortes, plus longues, plus intenses.

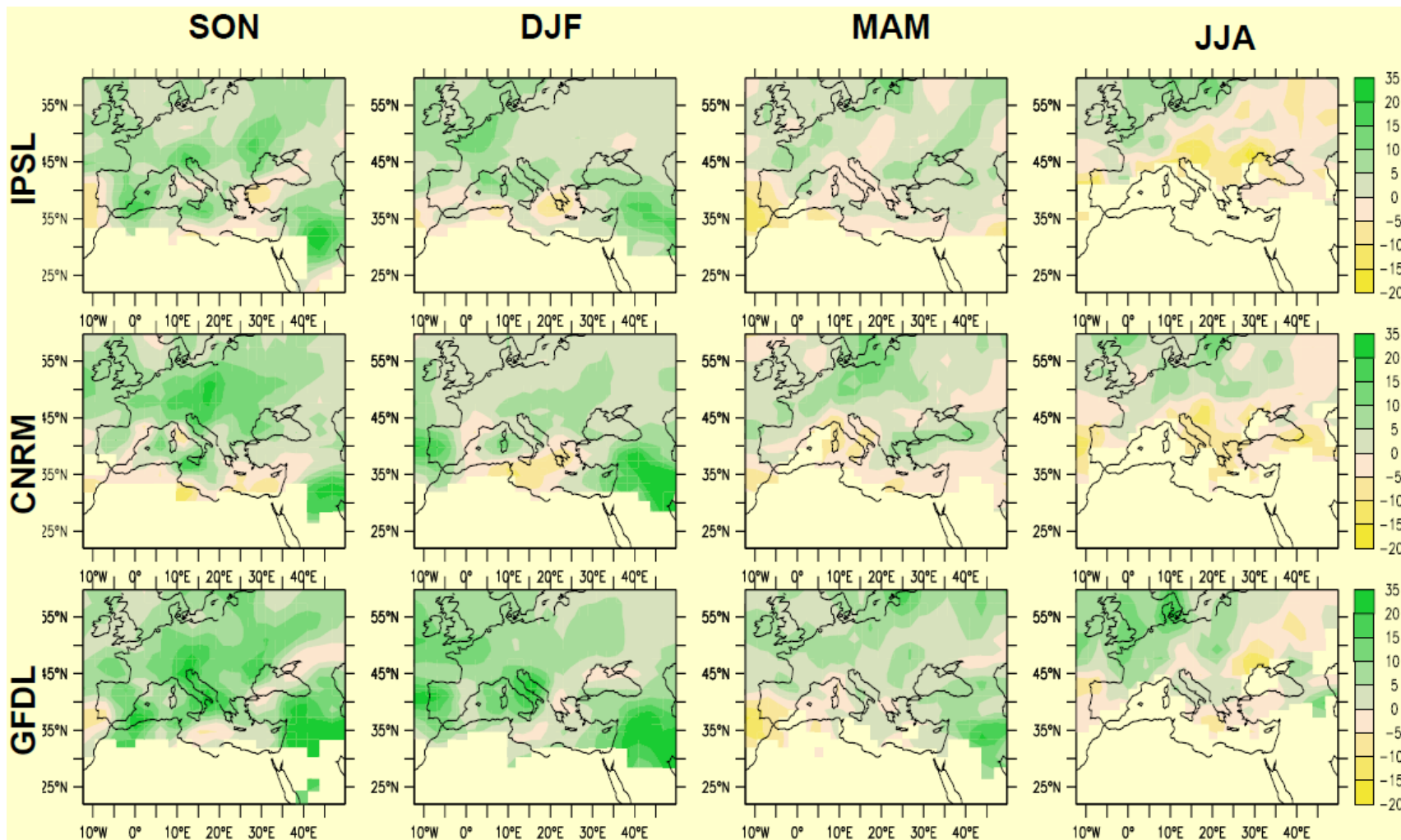
« À l'avenir, ces phénomènes seront plus intenses et fréquents »

Pour Philippe Drobinski, chercheur au CNRS, on manque encore de recul pour déterminer si ces événements sont déjà liés au réchauffement climatique.



Heavy precipitation and floods

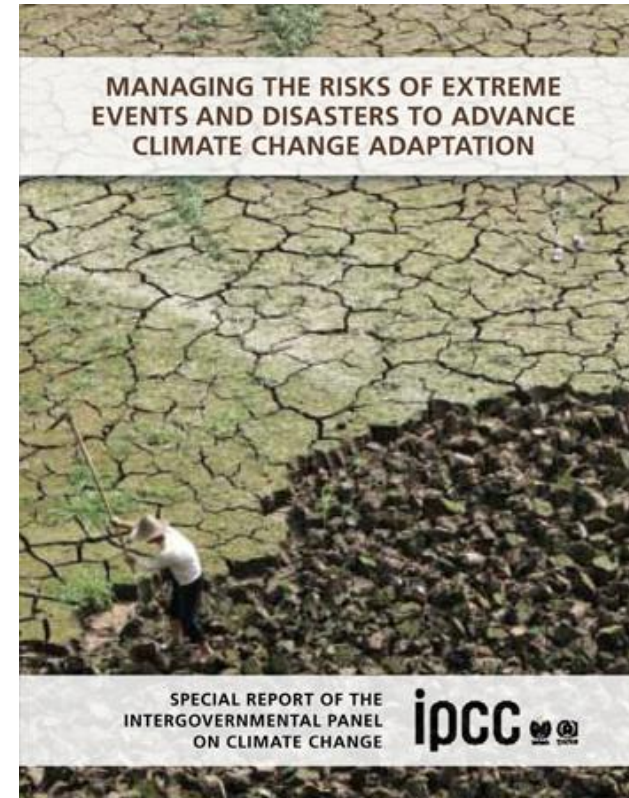
Extreme precipitation: 2070-2099



Heavy precipitation and floods

IPCC SREX (2012) report on the increase (or not) of floods

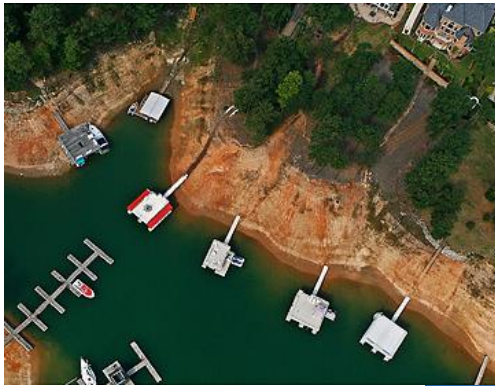
“... there is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales because the available instrumental records of floods at gauge stations are limited in space and time, and because of confounding effects of changes in land use and engineering. Furthermore, there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes ...”



Uncertainty driven by multiple indices, models, datasets, time periods ...

Droughts and heatwaves

Reduced water levels/supply: public, industry and power generation



NY Times



Reduced agricultural, forestry and fisheries productivity



Increased livestock mortality rates



BBC



Increased fire hazard/tree die off

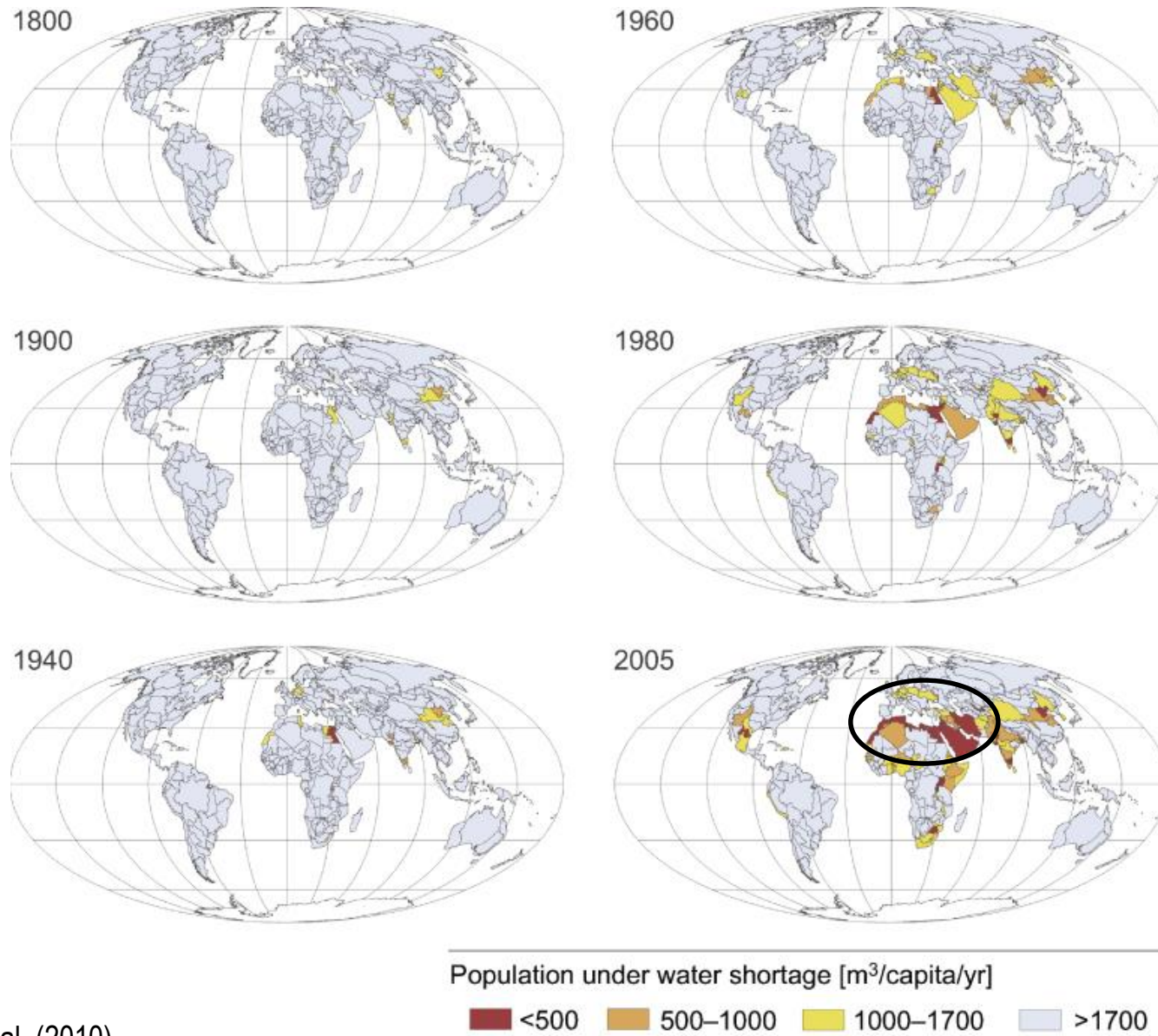
John Mccolgan/US Forest Service

Damage to wildlife habitat

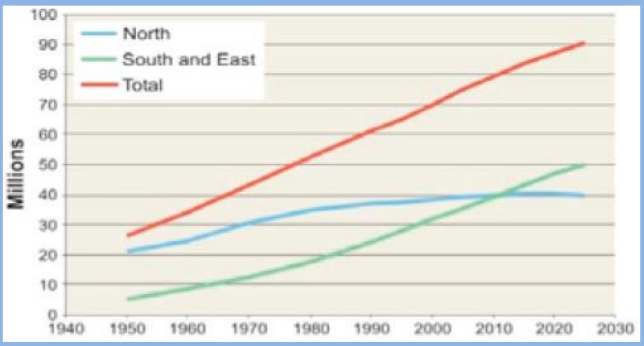


BBC

Droughts and heatwaves



Droughts and heatwaves



Population growth and changing demographics

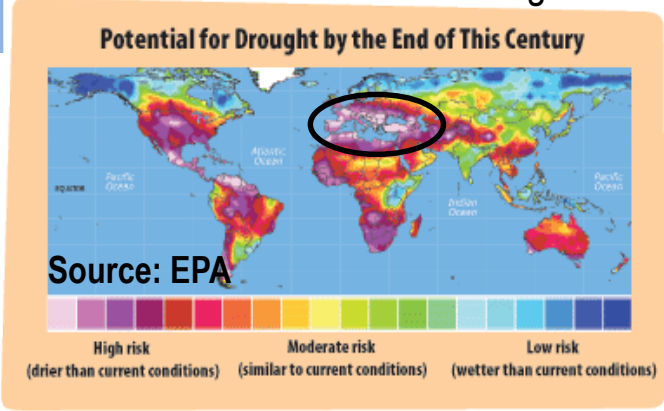
Agricultural demand and changing diets

What It Takes To Make A Quarter-Pound Hamburger

feed 6.7	Pounds of grains and forage	
water 52.8	Gallons for drinking water and irrigating feed crops	
land 74.5	Square feet for grazing and growing feed crops	
fossil fuel energy 1,036	Btus for feed production and transport. That's enough to power a typical microwave for 18 minutes.	

Source: J.L. Capper, Journal of Animal Science, July, 2011.
Credit: Producers: Eliza Barclay, Jessica Stoller-Conrad; Designer: Kevin Uhrmacher/NPR

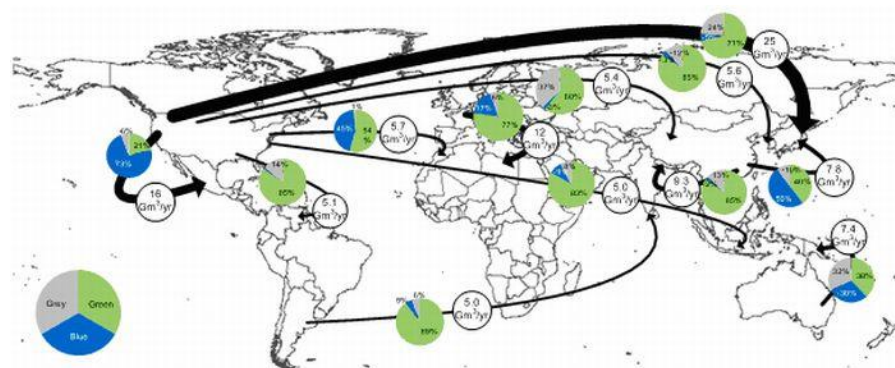
Climate Change



Unsustainable water use



We live in a connected world



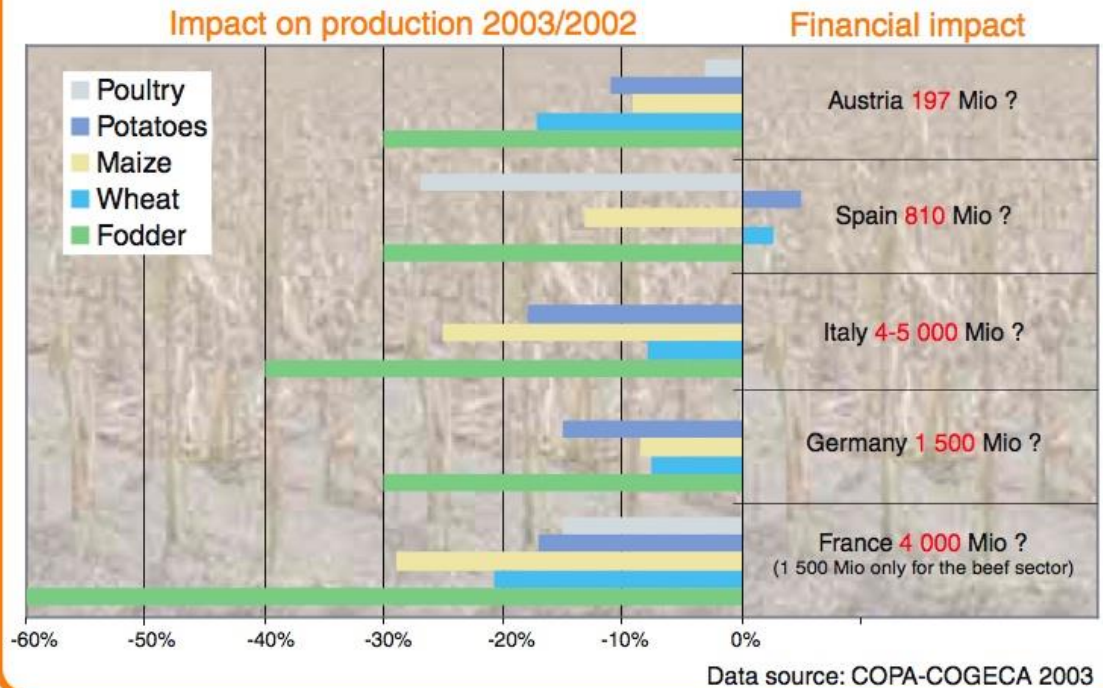
Droughts and heatwaves

Summer 2003 was the worst in 23 years for forest fires. 5.6% of forest area was lost.



Decrease of agricultural production

Impact of the summer 2003 heat wave and drought on agriculture and forestry in 5 selected countries



Droughts and heatwaves

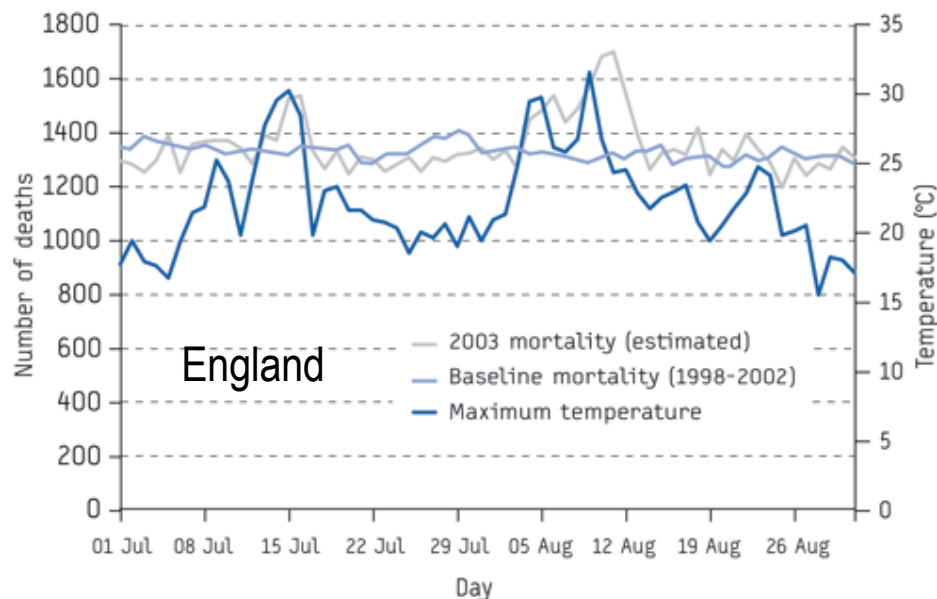
Increased mortality

http://ec.europa.eu/health/ph_information/dissemination/unexpected/unexpected_1_en.htm

© European Communities, 1995-2006

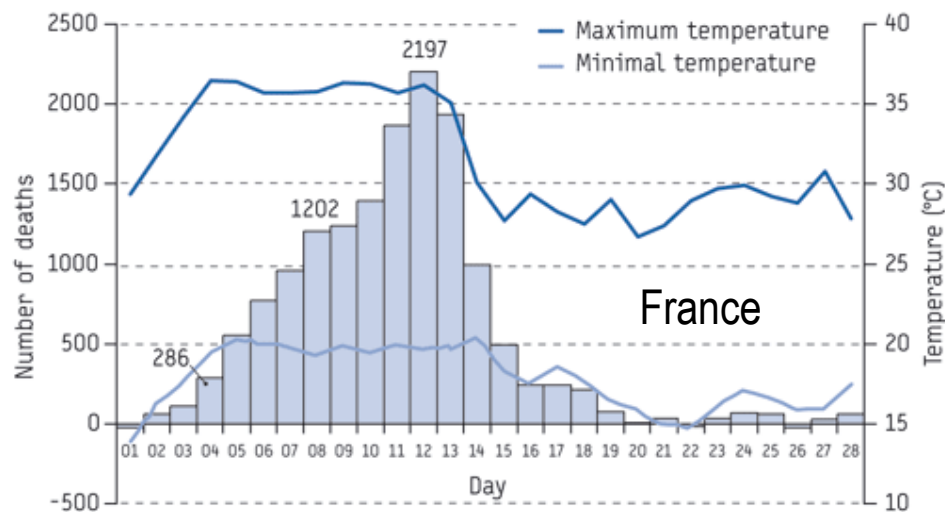
FIGURE 1

Maximum central England temperature and daily mortality, England and Wales, July and August 2003

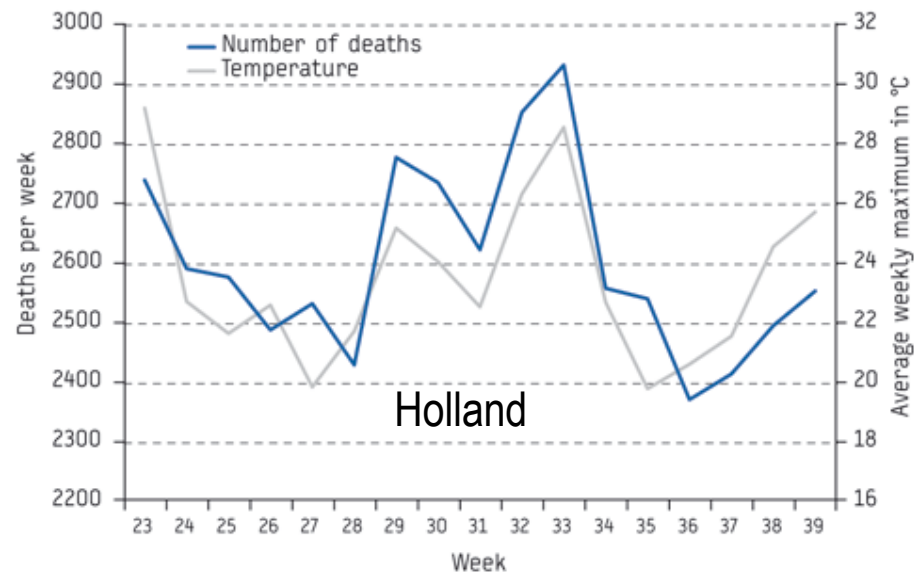


FIGURE

Daily excess of deaths during August 2003 and minimal and maximal daily temperatures, France

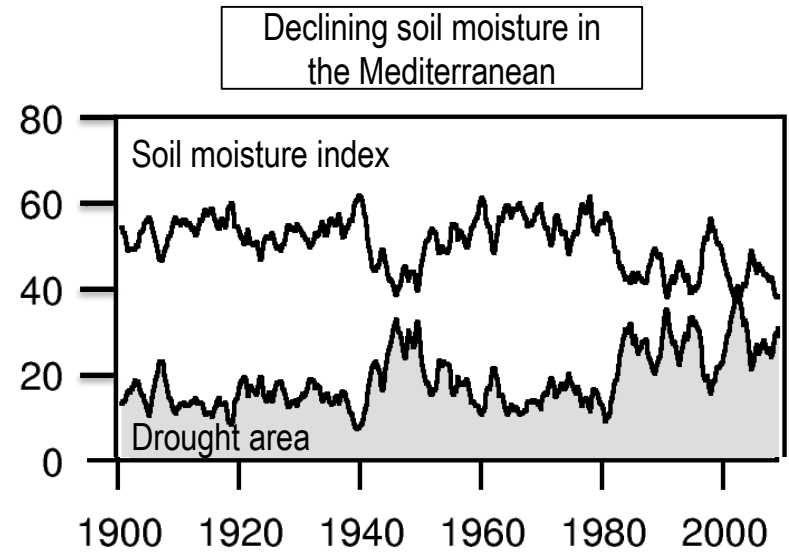
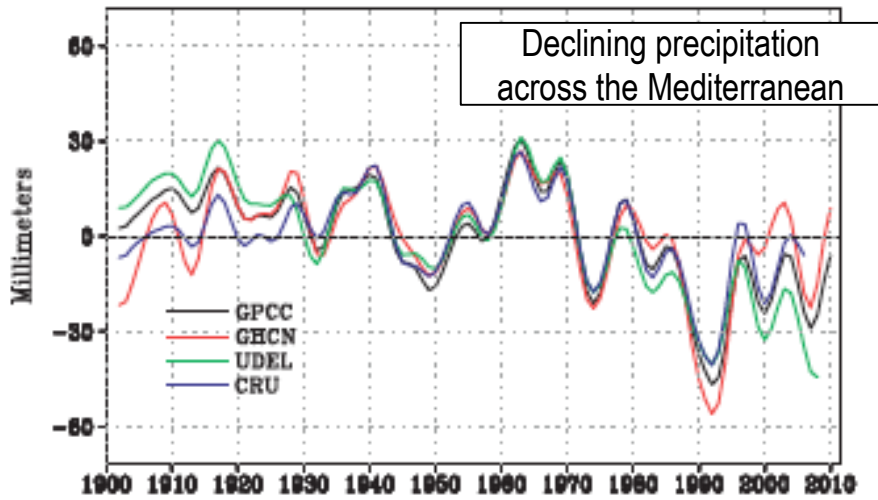


Mortality and average maximum temperature per week, The Netherlands, June-September 2003



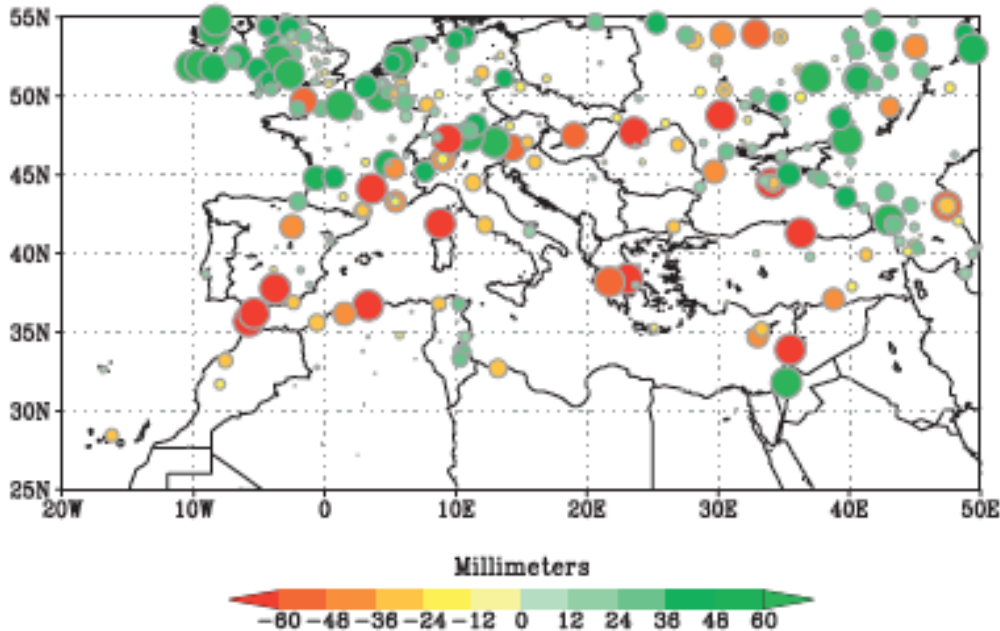
Source: [Ref. 1]

Droughts and heatwaves



Soil moisture from observation-forced land surface model simulations

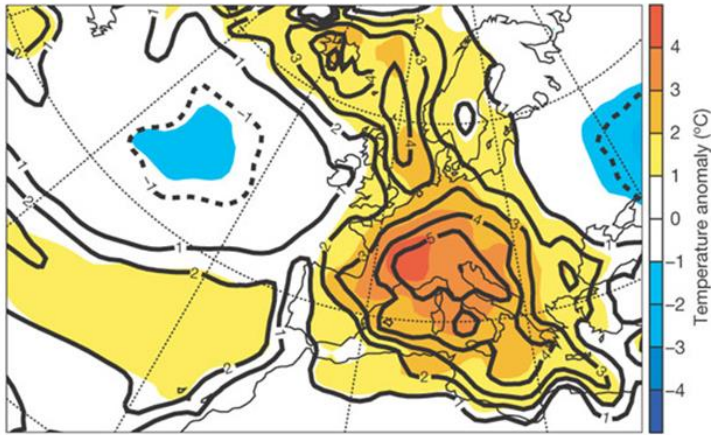
Source: Sheffield and Wood (2011)



Source: Hoerling et al. (2012)

Droughts and heatwaves

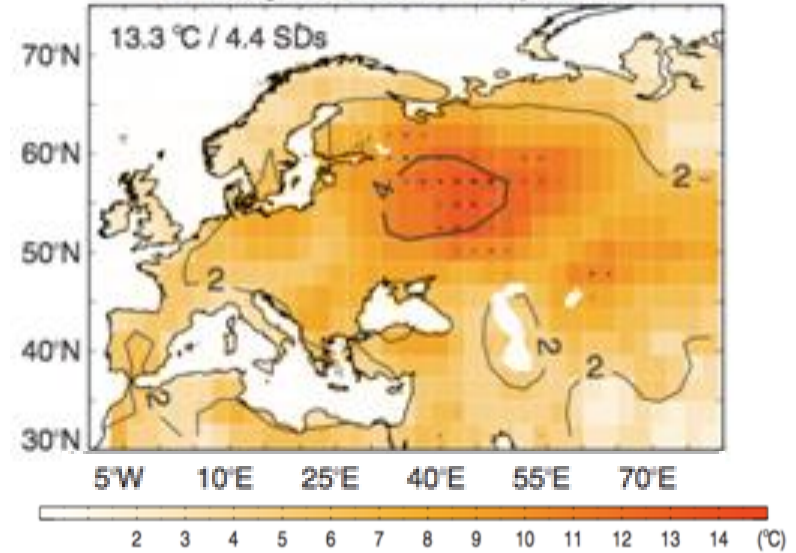
The 2003 heatwave in Europe



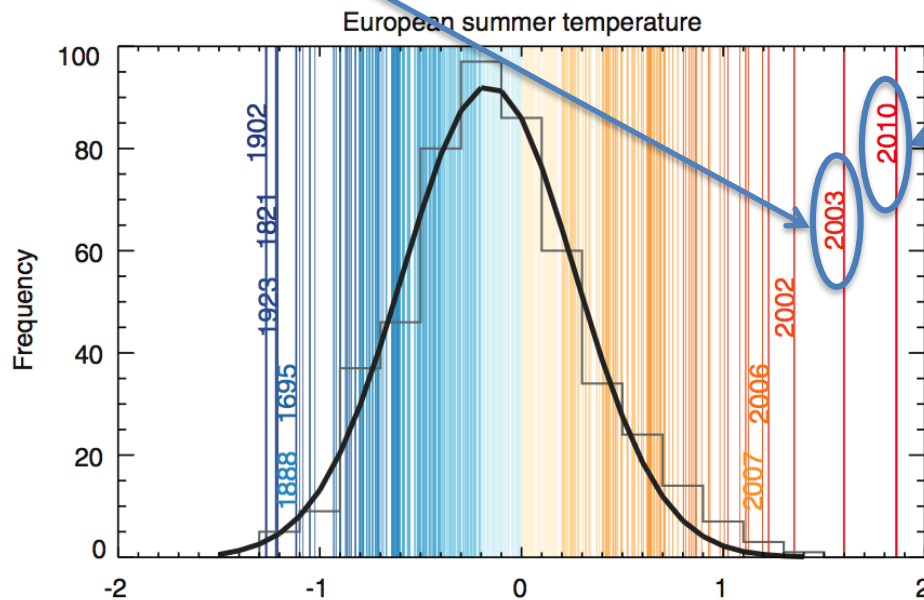
Source: Schär et al. (2004)

The 2010 heatwave in Russia

A 7-day maximum temperature

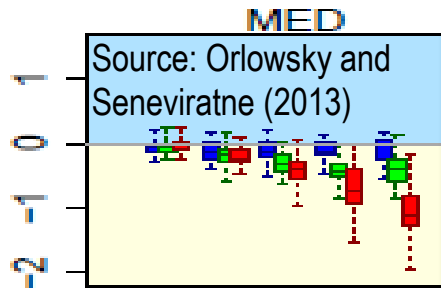


Source: Barriopedro et al. (2011)

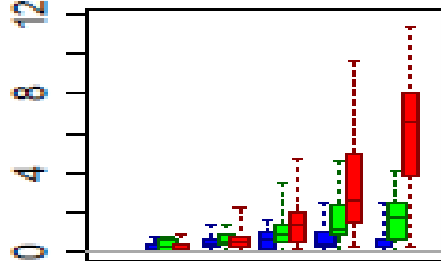


Droughts and heatwaves

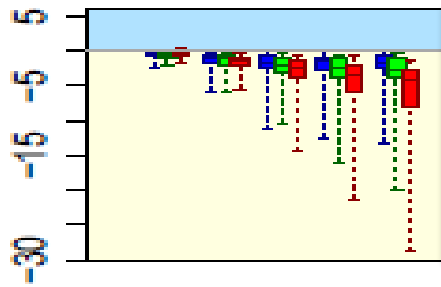
a SP112



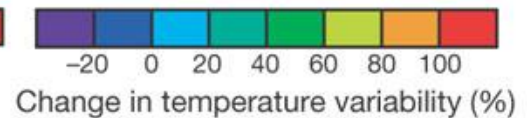
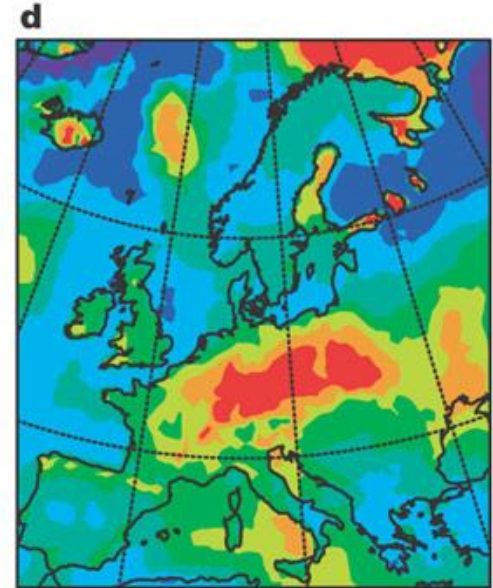
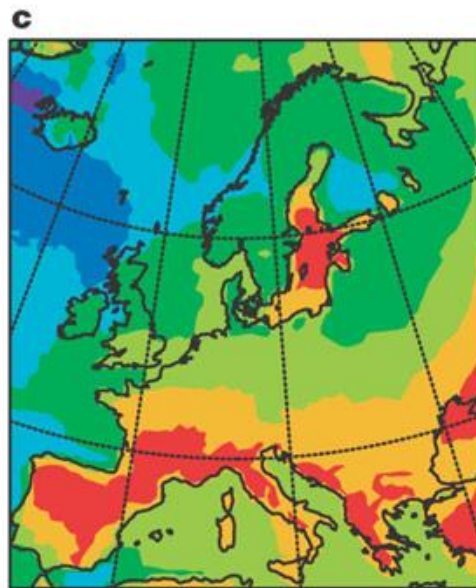
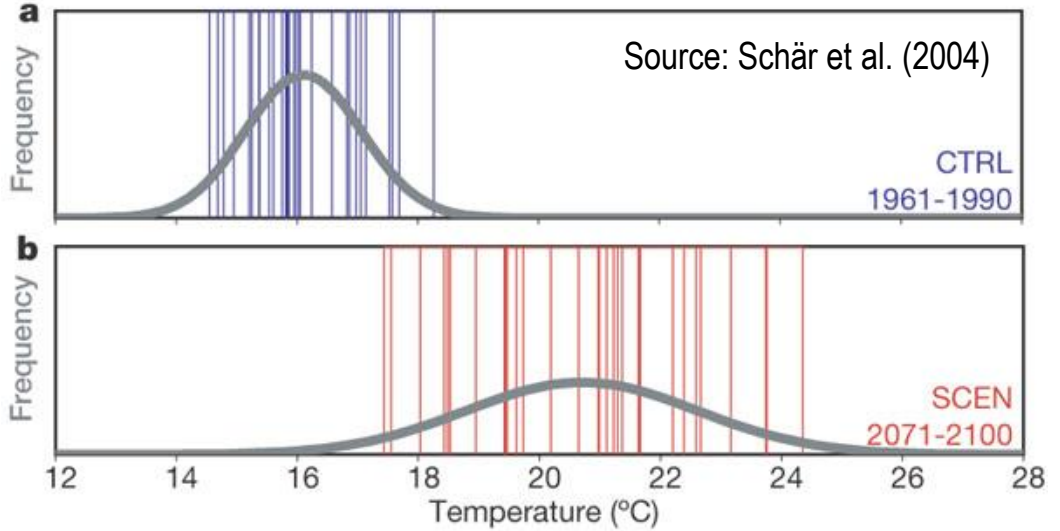
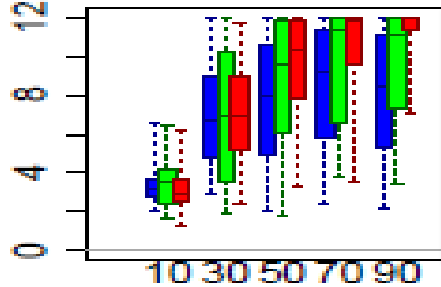
b Freq. SP112 < -1



c SMA



d Freq. SMA < -1



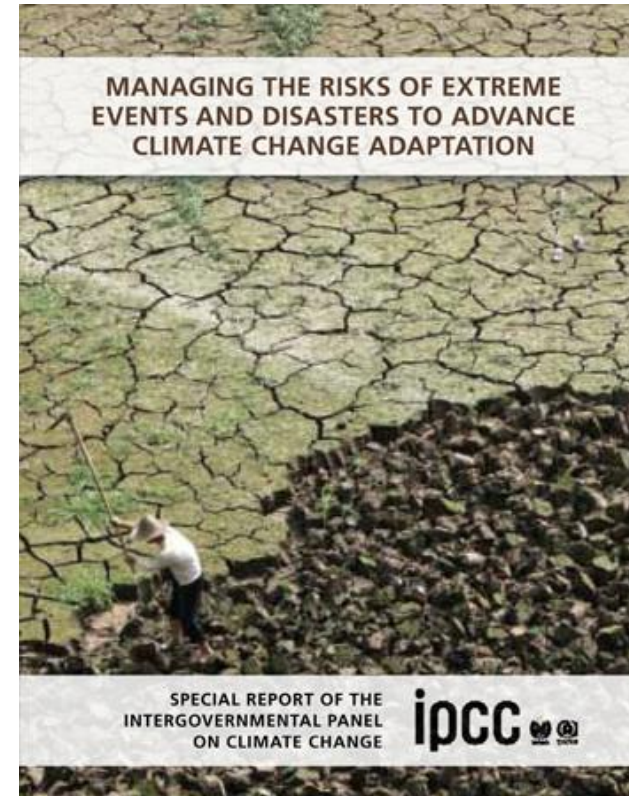
Droughts and heatwaves

IPCC SREX (2012) report on the increase (or not) of drought

“... there is medium confidence that since the 1950s some regions of the world have experienced **trends toward more intense and longer droughts**, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, central North America and northwestern Australia.

There is medium confidence that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes.

However there is low confidence in the attribution of changes in droughts at the level of single regions due to inconsistent or insufficient evidence”



Uncertainty driven by multiple indices, models, datasets, time periods ...

Some thoughts as a conclusion



* You'll see. If we raise the temperature very slowly, the frog does not notice anything



Nice - France
(October 2015)

*With these pessimistic
conclusions...*

... I thank you for your attention... Questions?



Maalula - Syria (April 2014)